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Measurement of the Luminosity by the ATLAS Experiment

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The luminosity is a fundamental parameter of a particle collider. The success of the physics programme of ATLAS depends on the precise determination of the luminosity. Several detectors have been used during the 2010-2011 data taking for the measurement of the luminosity and for monitoring its evolution as a function of time. The absolute calibration is performed using dedicated beam-separation scans which allows the determination of the luminosity without prior knowledge of the detector efficiency and inelastic pp cross section. Based on this method ATLAS has determined the luminosity with an uncertainty of 3.7%. A summary of the luminosity calibration methods and results are presented in this poster.

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1. Introduction

The luminosity in ATLAS is independently determined using several detectors and algorithms, each characterized by different acceptance, response to pile-up and sensitivity to background. The ratios of the luminosities obtained from these methods are monitored as a function of time and of the observed number of interactions per bunch crossing, μ_{vis}. The total luminosity can be written as:

$$\mathscr{L} = f_r \frac{\mu_{vis} n_b}{\sigma_{vis}} \tag{1.1}$$

where n_b is the number of colliding bunches, f_r the revolution frequency and σ_{vis} the visible cross-section. σ_{vis} corresponds to the total inelastic pp cross section times the detector acceptance, and it is measured for each detector with van der Meer (vdM) scans [4] . The vdM scan consists in moving the beam across each other in the transverse direction to determine the vertical and horizontal convolved beam size. The absolute luminosity is then derived as:

$$\mathscr{L} = f_r \frac{n_1 n_2}{2\pi \Sigma_x \Sigma_y} \tag{1.2}$$

where n_1, n_2 is the number of particles in the two colliding bunches and Σ_x, Σ_y are the horizontal and vertical convolved beam sizes.

This article describes briefly the determination of the ATLAS luminosity for the 2011 pp run at a center-of-mass energy of $\sqrt{s} = 7$ TeV. The detailed description of the analysis can be found in [1], [2] and [3].

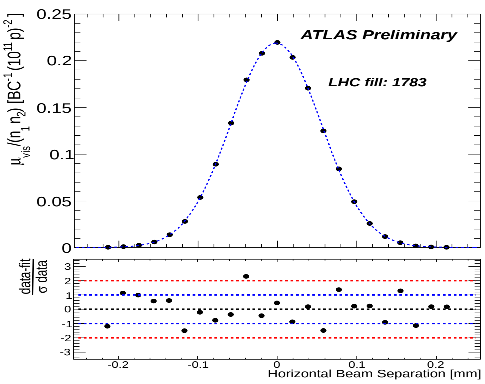
2. The ATLAS luminosity detectors and algorithms

The ATLAS strategy to understand and control the systematic uncertainties affecting the luminosity determination is to compare the measurements of several luminosity detectors. LUCID ($5.6 < |\eta| < 6$) and BCM ($|\eta| \sim 4$) are the two main detectors to measure the luminosity bunch-by-bunch. With an event-counting algorithm one relates the luminosity to the rate of events seen by a detector and passing a specific condition: OR (either detector side or both), AND (both detector sides), OR-A(C) (detector sides A, C inclusive).

In order to provide a cross-check of the stability and μ dependence of the LUCID and BCM algorithms, other measures have been performed using the Hadronic Calorimeter (TileCal, $0.8 < |\eta| < 1.7$) and the Forward Calorimeter (FCAL, $3.2 < |\eta| 4.9$).

3. Luminosity calibration with vdM scan method

In the beam separation scans, the observed event rate is recorded while scanning the two beams across each other, first in the horizontal (x), then in the vertical (y) direction. This measurement yields two bell-shaped curves per colliding bunch pair, with the maximum rate at zero separation, from which one extracts the values of Σ_x and Σ_y. As an example, Figure 1(a) shows the vdM scan data for a single colliding bunch pair and for a particular scan in the x plane. Each scan for each bunch pair is fit independently to a Gaussian function plus constant background to provide a measurement of μ_{vis}^{MAX} and Σ. Figure 1(b) shows Σ_x determinated by BCM algorithms for the 14 different bunch pair during a scan in 2011. A very good agreement is observed in the measurement of Σ for different algorithms.



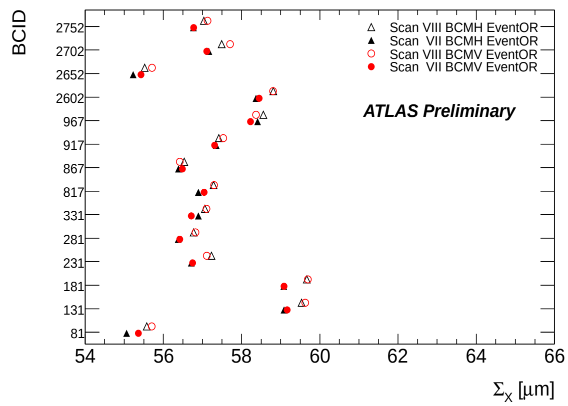


Figure 1: On the left the specific interaction rate vs the nominal separation for the BCMH_EventOR algorithm. On the right the horizontal beam convolved beam size determined by BCM algorithms for different colliding bunches.

Using Equation 1.1 and 1.2, it is possible to express σ_{vis} as a function of observable quantities for a given algorithm during the vdM scan:

$$\sigma_{vis} = \mu_{vis}^{MAX} \frac{2\pi\Sigma_x\Sigma_y}{n_1 n_2} \tag{3.1}$$

The visible cross-section of the reference algorithm (*BCMH_EventOR*) is determined to be $\sigma_{vis} = 4.689 \pm 0.159$ mb. σ_{vis} is used as the calibration constant to determine the luminosity. A detailed description of the systematic uncertainties is given in Ref. [2], the main contributions are the error in σ_{vis} due to vdM calibration ($\pm 3.4\%$), the long-term detector stability ($\pm 1.0\%$) and the uncertainty in the μ determination ($\pm 1.0\%$).

4. Conclusions

Measurements of the LHC luminosity have been performed by ATLAS in pp collisions at $\sqrt{s} = 7$ TeV using multiple detectors and algorithms. A relative luminosity uncertainty of $\delta\mathscr{L}/\mathscr{L} = \pm 3.7\%$ is obtained in 2011.

References

[1] ATLAS Collaboration, *Luminosity Determination in pp Collisions at $\sqrt{s} = 7TeV$ using the ATLAS Detector at the LHC*, *Eur. Phys. J.* **C71** (2011) 1630 [arXiv:1101.2185 [hep-ex]].

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[3] V. Hedberg, *Precision measurement of the luminosity in the ATLAS experiment, these proceedings*.

[4] S. van der Meer, *Calibration of the effective beam height in the ISR*, CERN-ISR-PO-68-31, 1968.